International Collaboration on Local Sand Transport Processes and Morphological Evolution

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LONG-TERM GOAL

To develop and enhance international collaboration in the area of coastal sediment transport processes.

SCIENTIFIC OBJECTIVES

The primary objectives of our collaboration are to further extend the theoretical and experimental investigations of the smaller-scale physical processes which must be incorporated in the development of a local model for sand transport and morphological evolution in coastal regions, including bedform prediction, local boundary layer hydrodynamics and a description of sediment dynamics covering the region from the immobile seabed to the overlying dilute suspension, incorporating both bedload and suspended load modes of sand transport.

APPROACH

We are integrating our various individual skills through a co-ordinated program of process evaluation, development, and validation. Process and model evaluation/development is being accomplished by building upon existing theories and models and by utilizing the comprehensive data sets that have already been obtained in large scale laboratories and field experiments (e.g. SANDY DUCK, the EC MAST programme) or have been undertaken with NICOP assistance (SISTEX99 in Hannover, Germany, Percolation experiments in Brisbane, and the Novosibirsk field campaign).

WORK COMPLETED

Fieldwork associated with SANDYDUCK, SISTEX99 and UQ Percolation experiments

RESULTS

<u>**SISTEX99** (**S**mall-scale **I**nternational **S**ediment **T**ransport **Ex**periments 19**99**):</u> in the Large Wave Flume in Hannover, Germany (TMR-framework (EU) and NICOP). Universities of Twente (UT), East Anglia (UEA), Florida (UF) and Santa Barbara, California (UCSB) in collaboration with Franzius Institute and the Large Wave Flume of the University of Hannover, Delft University of Technology, Proudman Oceanographic Laboratory, Albatros Flow Research, and University of Utrecht. The experimental set-up was described in our FY1999 report and an overview of the project presented at ICCE2000 in Sydney in July (Ribberink et al., 2000). The large data set is now under detailed analysis and evaluation under three main topics.

Sheet Flow. Novel instruments enabling concentration and velocity to be measured within and just above the bed (at sub-millimetre scale) are producing spectacular results and altering many of our ideas about the processes occurring in sheet flow. Figure 1 shows an example of the horizontal orbital velocity at 0.1 m above the bed under a wave group (left panel) and the corresponding sediment concentrations at different levels inside the sheet flow layer (right panel). As expected, the concentration inside the sheet flow layer reacts almost instantaneously to changes in the near-bed velocity. The behavior is very similar to that observed in the past in a large oscillating water tunnel.

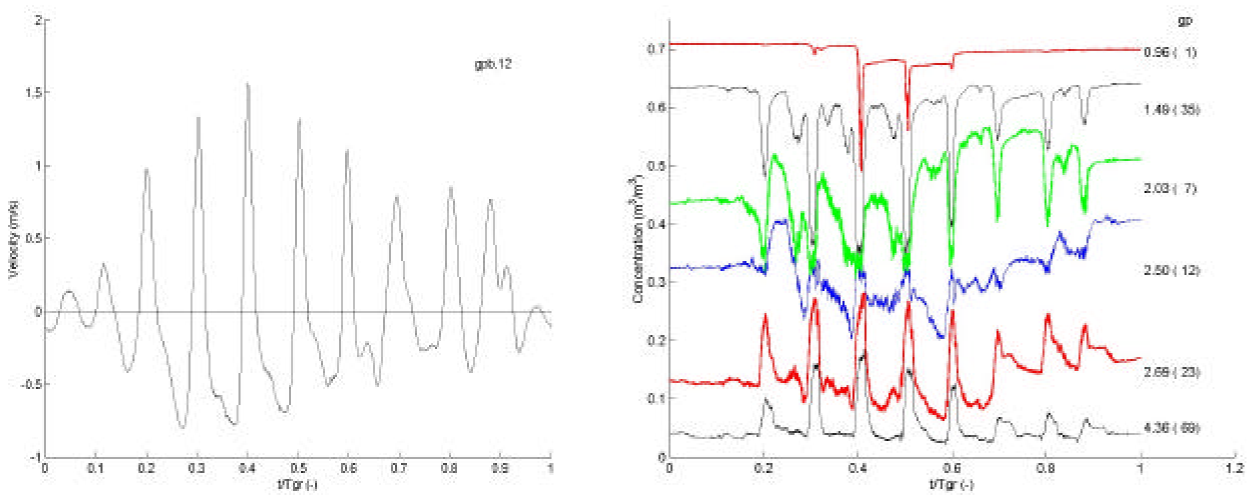

Figure 1 Velocity under a wave group and concentrations between 0.96 and 4.36mm ('bed' at 2.5mm)

Vertical velocities from Coherent Doppler. An acoustic coherent Doppler system was used to measure the fine-scale vertical velocity profiles and co-located concentration profiles over rippled and smooth beds. Although the shape of the surface elevation due to the waves was well-described by cnoidal wave theory the vertical currents show regular and marked periods of deviation, particularly at times of flow reversal after the passage of the wave crest. These anomalous velocities are associated with times of high suspended load concentrations and are similar to the features observed over flat beds by Ribberink & Al-Salem (1992) and Black & Vincent (2000). The mechanism suggested is of a period of enhanced turbulence generation associated with the high shear close to the seabed around flow reversal. Results were presented at the UK Marine Sciences 2000 conference

Pump-up by waves and wave groups Suspended sand concentrations are observed to lag the forcing waves, with the lag increasing with distance from the sea bed. In the SISTEX99 experiments the near-bed (1-2cm) concentrations typically reached an equilibrium 1-2 wave-periods after the waves themselves had reached their maximum height while at 10-15cm the lag was several waves longer (figure 2). This was interpreted as due to the continual injection of turbulence into the water column from vortex processes associated with the oscillatory wave boundary layer over bedforms. Wave-average concentration profiles were dominantly advective although, for some higher waves, sections of the profiles close to the bed were diffusive in character. A similar pattern was seen for wave groups, with the sand concentration near the bed lagging by 1-2 waves and the lag tending to increase with distance from the bed. A simple total-load model is proposed to describe the major features of the suspension and to allow prediction of the lag of the suspended sediment in relation to the wave group, important for assessing the transport of sand at infra-gravity frequencies.

The total-load in suspension $W(N)$ during the Nth wave is

$$W(N) = C\sum_{j=N}^{j=N-15} q^{p}(j)\exp(-k(N-j)T)$$

where è is the skin-friction Shields Number, T is the wave period, C is an entrainment or pickup constant, p is an integer 1,2 or 3 and k is the rate of decay of turbulence. The model has been calibrated using 5 wave groups and tested using a number of other wave conditions, including random waves and wave records from the SANDYDUCK field campaign. When the decay term is included the predictability of the total load by the Shield's Number è is increased significantly as measured by both the variance explained and the mean absolute error.

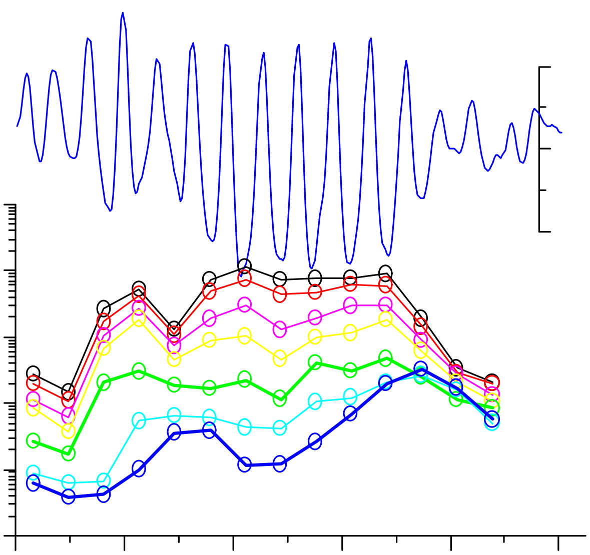

Figure 2 Wave horizontal velocity (top panel) and wave-average concentration profiles at 1, 2, 4, 6, 10, 15 and 20 cm

Percolation Experiments:

The influence of percolation on suspended sediment concentrations and the growth of bed forms; University of Brisbane in collaboration with students from UEA, DUT and the University of Paris. Experimental work is continuing in the purpose-built flume at the University of Queensland to quantify the stabilising effect on sediment particles of infiltration and the competing destabilising effect of increased bed shear stresses generated by the same infiltration. Details of the flume etc are given in our FY1999 report. The work the effects of percolation on ripple growth and bed mobility has been completed and accepted for publication in Coastal Engineering (Nielsen et al., 2000). Further studies this year (UQ and UEA) have been conducted on the effects on sand suspension of percolation, using acoustic backscatter, at a variety of wave heights under regular waves. Preliminary results show a strong influence of percolation (figure 3) indicating that at the grain size used (D_{50} of 240ìm) percolation stabilised the bed (the stabilising effect of dominating over the increased bed stress). Results will be presented at the December AGU.

Russian Field Experiments:

Vertical sorting of suspended sediment particles by size, density and shape in the nearshore zone on the Novosibirsk Reservoir in Russia; Institute for Water and Environmental Problems, Barnaul, Russia. Vertical sorting of suspended sediment by sediment grain size, density and shape of separate particles due to waves was studied at the Novosibirsk Reservoir barred and non-barred beach of sand origin. Field observations revealed 3 major types of the sediment parameters profiles:

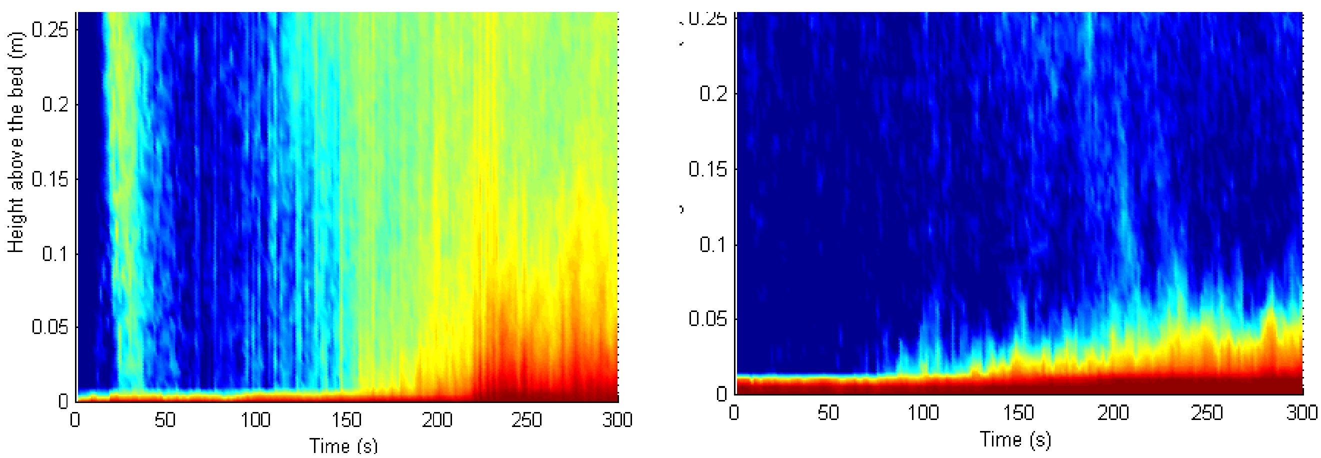

Figure 3 Suspension from sand bed as a function of time since wave generated starts (T=1.8s, H=0.22m) Left panel – no percolation, Right panel – with percolation. Colour scale is logarithmic, red >1g/l, blue<0.01g/l

1. Profiles characterised by a quasi-steady decrease of all sediment parameters away from the seabed – suspended concentration, grain size, heavy minerals and content of well-rounded particles content (Fig. 4). Well-rounded particles are those with a Rilei coefficient of sphericity $R_{sp} \geq 0.75$. Usually such profiles occurred just after the storm onset when the wave height was increasing or under the decreasing wave heights. As the significant wave height reached its maximum, they were observed mainly at the lower part of cross-shore profiles mainly at a depth of closure.

2. Profiles of the second type were distinguished by a local peak of the suspended sediment concentration at some distance from the bed and by simultaneous changes in well-rounded particle content. Changes of the sediment grain size and the heavy minerals content showed a tendency similar to the first case, i.e. their quasi-steady decrease toward the water surface. This type of suspended sediment profile was observed everywhere over the nearshore in all phases of the storm.

3. Finally, the last type of suspended sediment profiles is characterized by the monotone decrease in the suspended sediment concentration and the sediment grain size from the bed toward the water surface, while both the heavy minerals and well-rolled particles content profiles have local peaks over the bed. To judge from few video-images such a pattern took place when the flow intensity was the highest, bedforms like ripples were not presented and the sheet flow was observed.

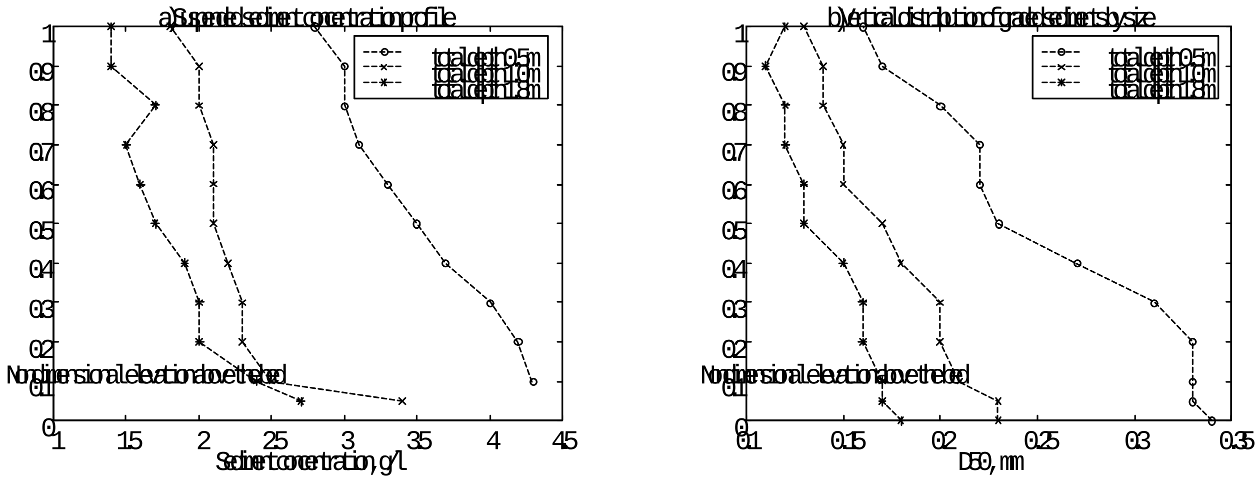

Figure 4 Type 1 suspended sediment concentration profiles (left panel) and size D50 profiles (right panel)

IMPACT/APPLICATION

Small-scale sediment processes are integral to understanding many engineering applications involving dynamics near the seabed. We believe the results from the collaborations described above are essential for the development of process-based, predictive models that can accurately describe sediment transport and the morphodynamic evolution of coasts.

TRANSITIONS

1) A new SISTEX is being planned for the 2001/2002 time frame.

2) Results of our modelling efforts will be incorporated into the NOPP nearshore model.

The following could be added, though it is still in review:.

RELATED PROJECTS

Each of the Principal Investigators have ongoing related research projects

PUBLICATIONS

Hanes D.M., V Alymov, E D Thosteson, Y Chang, C E Vincent. (1998) Local Seabed Morphology and Small Scale Sedimentation Processes During SANDYDUCK97. EOS (abstract only).

Vincent C.E., K Black, D M Hanes (1998) Fine-scale resuspension processes by waves over flat and rippled beds: field observations. EOS (abstract only).

Dohmen-Janssen, C.M., 1999. Sheet flow under monochromatic waves and wave groups. Set-up of CCM measurements in the Large Wave Flume, Hannover. *Civil Eng. & Management Research Report 99R-016/MICS-006, University of Twente, The Netherlands, 26 pp.*

Ribberink, J.S., C.M. Dohmen-Janssen, D.M. Hanes, S.R. McLean, J.A. Taylor and C. Vincent (2000) Near-bed sand transport mechanisms under waves: large-scale flume experiments. 27th Int. Conf. on Coast. Eng.(ICCE 2000), ASCE, Sydney.

Dohmen-Janssen, C.M., 2000. Sheet flow under monochromatic waves and wave groups. CCM measurements in the Large Wave Flume, Hannover. *Civil Eng. & Management Research Report 2000R-003/MICS-012, University of Twente, The Netherlands, 54 pp.*

K.P. Black and C.E. Vincent.(in press) Sediment suspension under shoaling waves: high-resolution field measurements and numerical models. Coastal Engineering.

McLean, S.R. J.S. Ribberink, C.M. Dohmen-Janssen and W.N.Hassan (in press) Sand Transport in Oscillatory Sheet Flow with Mean Current. J of Waterways, Ports, Coastal and Ocean Engineering, ASCE.

Hanes, D.M.,V. Alymov, and C.D. Jette, Wave formed sand ripples at Duck, North Carolina, Journal of Geophysical Research, (under review)

Thorne P.D and D.M. Hanes. A review of acoustic measurements of small-scale sediment processes. Continental Shelf Research (under review)

COLLABORATION

Dates	Personnel	Activity
Oct 1999- Sept 2000	Dr Marjolein Dohmen-Janssen (UT) collaborating with Theo Westgeest from Delft University of Technology	Analysis of net transport rates, measured in a large wave flume (SISTEX99)
Oct 1999 – Sept 2000	Oleg Muraenko (Russian graduate student) at UF.	Training in Coastal Engineering
29 Nov – 10 Dec 1999	Dr Marjolein Dohmen-Janssen (UT) to UCSB to work with Dr Steve McLean	processing of sheet flow data, measured in a large wave flume (SISTEX99).
10 - 19 Dec 1999	Dr Chris Vincent to University of Florida (Dr Dan Hanes)	SISTEX 99 data analysis and preparation of papers for publication
13 – 16 Dec 1999	Dr Marjolein Dohmen-Janssen (UT) and Dr Steve McLean (UCSB) to AGU-Fall meeting	presenting/discussing sheet flow data, measured in a large wave flume (SISTEX).
7-11 Feb 2000	Luke Gillan (UQ) visit to UT to work with	analysis of data from a large oscillating

	Dr Marjolein Dohmen-Janssen (UT)	water tunnel
3 – 4 Apr 2000	Dr Jan Ribberink and Dr Marjolein Dohmen-Janssen (UT), Dr Steve McLean (UCSB) and Dr Dan Hanes (UF) visit to Molde, Norway	participation in SEDMOC-workshop (EU project on sediment transport processes and modelling)
5 – 6 Apr 2000	Dr Jan Ribberink and Dr Marjolein Dohmen-Janssen (UT), Dr Steve McLean (UCSB) and Dr Dan Hanes (UF) visit to Molde, Norway	workshop to discuss results of SISTEX99 and make plans for new experiments
15-16 July 2000	Dr Dan Hanes, Dr Steve McLean (UCSB) Dr Jan Ribberink and Dr Marjolein Dohmen-Janssen (UT), Dr Chris Vincent and Charlie Obhrai (UEA) visit to Sydney, Australia	Progress meeting and workshop to discuss results of SISTEX99 and make plans for new experiments
17-22 July 2000	Dr Jan Ribberink and dr Marjolein Dohmen-Janssen (UT), Dr Dan Hanes, Dr Chris Vincent and Charlie Obhrai (UEA), Dr Steve McLean (UCSB), Dr Alex Khabidov and Dr Peter Nielsen and Luke Gillan (UQ) visit to Sydney, Australia	Attendance and participation in International Conference on Coastal Engineering (ICCE2000)
25 July – 15 August 2000	Prof Chris Vincent and Charlie Obhrai to University of Queensland (Dr Peter Nielsen)	Percolation experiments using the University of Queensland wave tank and UEA acoustic equipment
25-26 July	Dr Steve McLean visits Dr Peter Nielsen at University of Queensland	Collaboration on sheet flow processes